# Advanced Projects in Exoplanets

## The RM Effect

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# Transiting Exoplanets

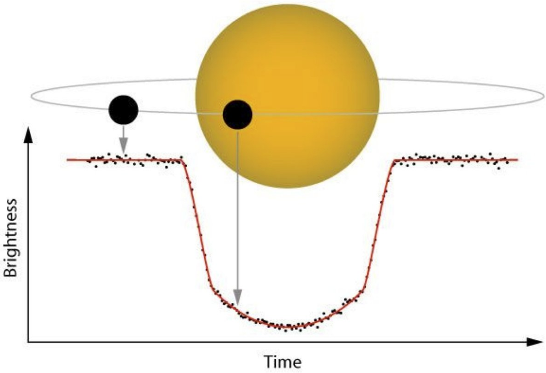



Figure: *Credit ESO*

# Rossiter-McLaughlin Effect

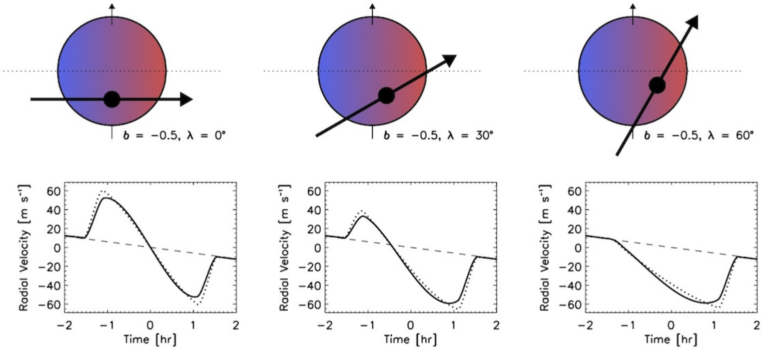



Figure:
https://wasp-planets.net/tag/rossiter-mclaughlin-effect/

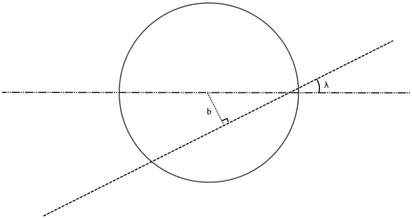
# Our Model - Linear

Planet moves in straight line in front of the star

This path is determined by:

- Projected obliquity
- Impact parameter

This model is not physical



# Keplers Equations

To get $r(t)$:
Calculate mean anomaly:

$$M(t) = \sqrt{\frac{G(M_\star + M_p)}{a^3}} \cdot (t - t_p).$$

Calculate eccentric anomaly by numerical iteration:

$$E_{n+1} = E_n - \frac{E_n - esin(E_n) - M(t)}{1 - esin(E - n)}.$$

Calculate true anomaly:

$$\nu(t) = 2\tan^{-1}(\left(\frac{1+e}{1-e}\right)^{1/2} \tan(E(t)/2)).$$

Calculate separation:

$$r(t) = a\frac{1-e^2}{1+ecos(\nu(t))}.$$

# Our Model - Physical version

Planet orbits the star.
Keplers equation is solved for input parameters.
The path is determined by:
$a$, $e$, $i$, $\omega$, $M_\star$, $M_p$, $t_p$, $\lambda$, $R_p/R_\star$ and $v\sin(i_\star)$.
Much more resource heavy, but also correct

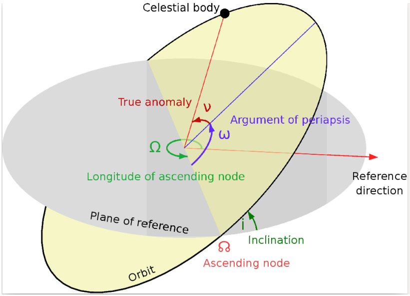



Figure: Credit: Wikipedia user Lassuncty

# Modelling Planet Orbit

Calculate projected coordinates of the planet:

$$X_i = -r cos(\omega + \nu),$$
$$Y_i = -r sin(\omega + \nu) cos(i).$$

$$X = X_i cos(\lambda) + Y_i sin(\lambda),$$
$$Y = -X_i sin(\lambda) + Y_i cos(\lambda),$$
$$Z = r sin(\omega + \nu) sin(i).$$

# Our Model - Outputs

[Video here]

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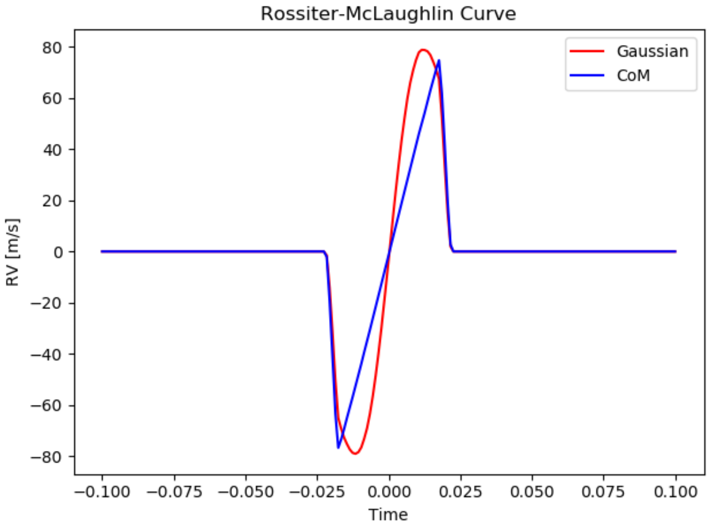
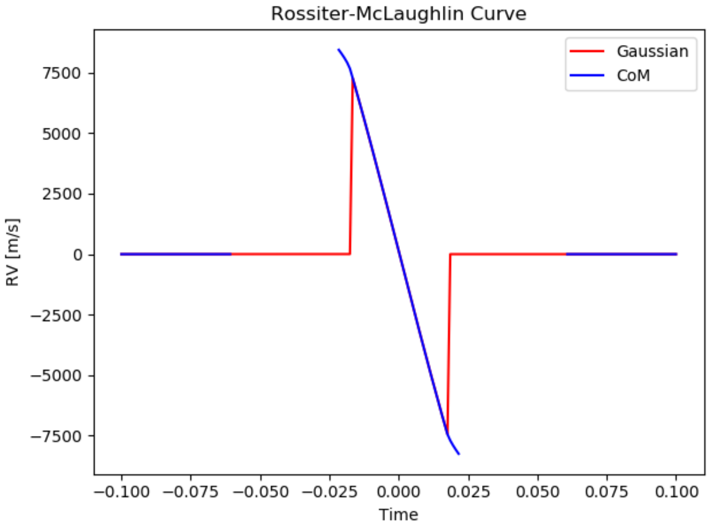
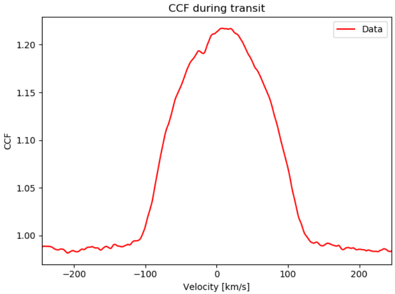


# Our Model - Outputs

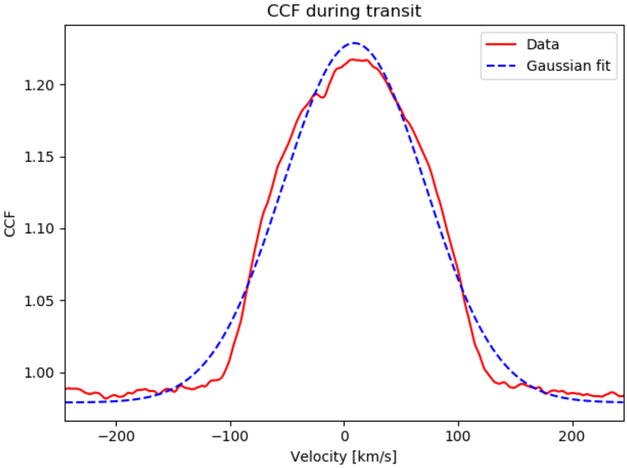


# Data

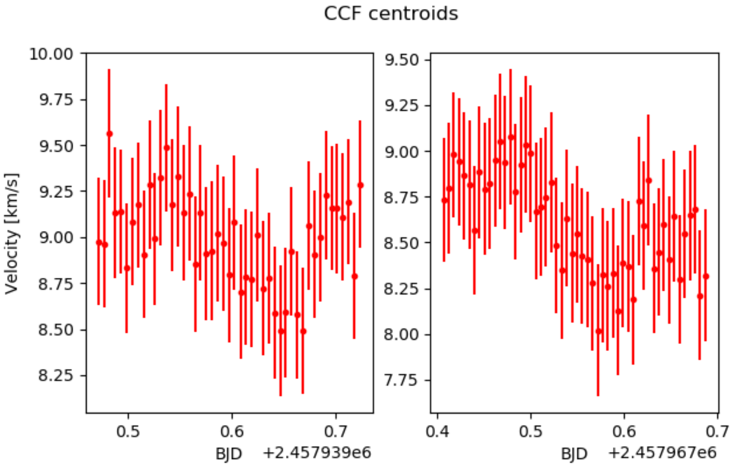
Data is of the star MASCARA-1 and comes from HARPS. Consists of BJD and CCF.



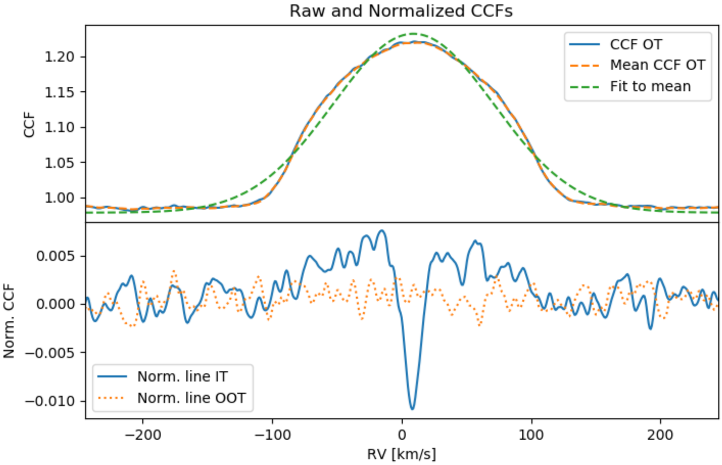
# Data - The stellar line



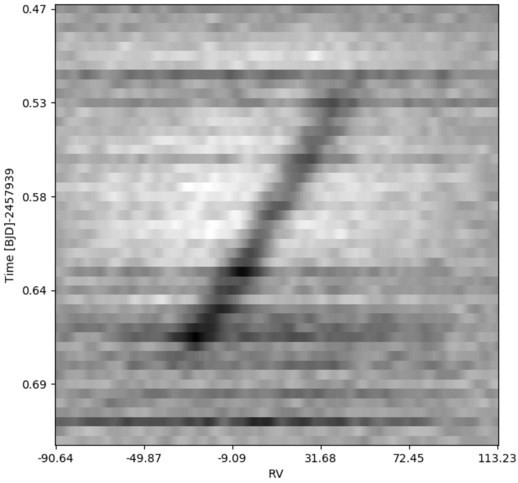
# Data - The Transit



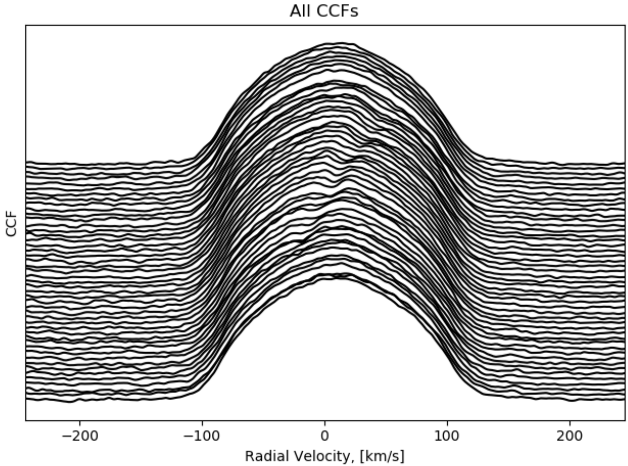
# Data - The 'Planet Line'



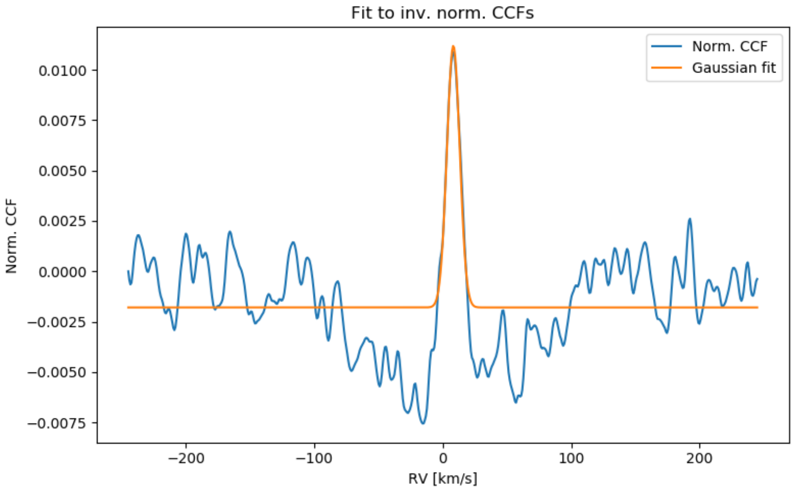
# Data - The RM-effect



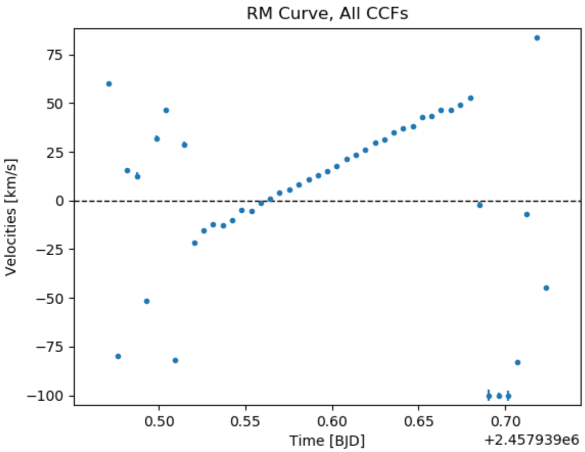
# Data



# Data - Fit to CCF



# Data - RM curve



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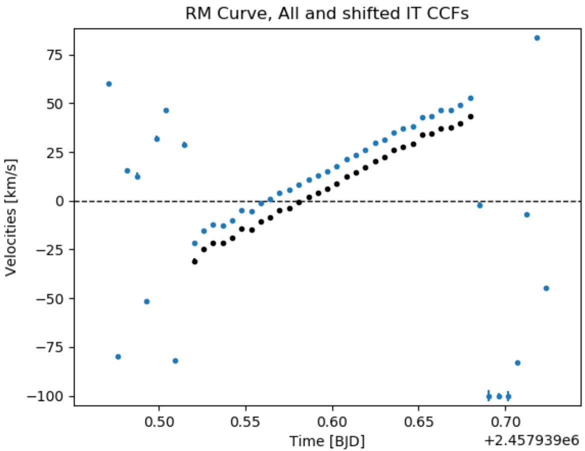
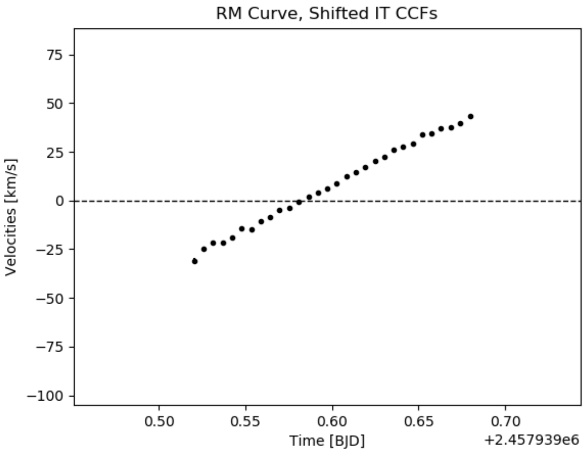


# Data - RM curve



# The Fit - System Parameters

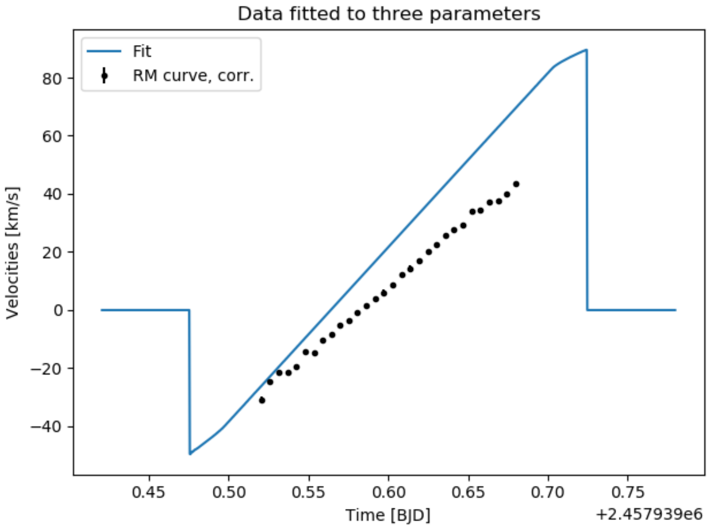
Variables:

- $\lambda$
- $\omega$
- $v \sin(i_\star)$

Constants:

- $t_p = 0$
- $a = 4.756 R_\star$
- $e = 0$
- $M_\star = 1.72 M_\odot$
- $M_p = 3.7 M_J$
- $\frac{R_p}{R_\star} = 0.0735$
- $\omega = 90^\circ$

# Fitting with curvefit



# Linear fit